THE

Indian Tea Association.

SCIENTIFIC DEPARTMENT

QUARTERLY JOURNAL.

PART IV.

1929.

Calcutta:
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PREVENTION OF DISEASE IN YOUNG NURSERIES

In the course of the past year many unsatisfactory seedlings have been received at Tocklai. The cause of their poor growth is in most cases due to the attacks of fungi or Eelworm during the very early stages of their growth. This kind of thing cannot be cured but it may be largely prevented by paying special attention to the preparation of the nursery site. The following suggestions may be found useful in the connection.

A heavy dressing of mature cattle manure may be given to the site if considered necessary at least a month before the nursery is to be used. The manure should be spread evenly over the soil. A hoe should then be given. All clods should then be broken and grass and jungle roots removed. This proceeding will help to mix in the manure thoroughly. Beds may now be prepared. The surface of the nursery site should now be of fine soil with no lumps.

The next thing to do is to throw up the surface of the beds into ridges about six inches high and of the same width. This is suggested with a view to increasing the surface area for the subsequent operation. The whole site should then be covered with six inches of dry thatch or other readily burnable rubbish. This should be burned about a week before the seed is sown. After the burning the surface of each bed should be raked flat again. The subsoil should not be disturbed again, otherwise there is a danger of preventing the subsoil water rising to the surface. If this happens in some soils the subsequent watering of the surface soil does not establish the contact satisfactorily and many of the seeds may remain in a layer of dry earth. In any case it is advisable when planting ungerminated seed to beat the dry surface of the beds after the seed has been sown. When planting seed already germinated care should be taken to press the earth round the seeds.

After the seed has been sown the nursery should be shaded. The shading should be high enough for children to walk under-

neath it with ease. The lower edge of the thatch roof should be sufficiently wide so that the drip will fall in the channel between the beds and not splash on the seedlings on either side. The practice of covering the beds with layers of thatch is a very bad one as it encourages the growth of many fungi. All the precautions taken to avoid fungi and Eelworm would be of no avail if rotting thatch be allowed to remain in contact with the young plants.

In spite of all precautions taken in preparing the site an unsatisfactory nursery may be obtained if the seed has not been properly looked after. It is of the utmost importance to prevent undue loss of moisture from the seed during storage. Our experiments have indicated that one of the causes of twisted stems and roots is the result of undue loss of moisture from the seed before it is planted. It is wise to plant out the seed as soon as possible after receipt. If it is necessary to store it for some time it may be placed in a cool spot, such as a corner of the fermenting room, and mixed with a large quantity of damp powdered charcoal. Storage in sand or earth in pits is not very safe as the sand or earth may be infected with fungi or Eelworm and would then have a good chance of infecting the seed. Charcoal, however, is more or less sterile. Coarse sand obtained direct from a river bed is fairly safe and may be used in the germinating pits.

A. C. T.

LECTURE GIVEN BY MR. S. F. BENTON, B. Sc., TO THE MEMBERS OF THE TEA BROKERS' ASSOCIATION OF LONDON.

Copy of a LECTURE GIVEN BY MR. S. F. BENTON, B.Sc., Bacteriologist, Scientific Department, Indian Tea Association, to the members of the Tea Brokers' Association of London at the London Commercial Sale Rooms, on Thursday, the 12th September 1929.

The Chairman of the Tea Brokers' Association (Mr. E. M. Murray) presided and introduced Mr. Benton, who then addressed the meeting as follows :—

Mr. Chairman and Gentlemen :—

I am very glad to have this opportunity of saying a few words on the Bacteria Associated with tea, particularly in reference to tea taints.

The idea of bacteria in tea may at first thought appear to be rather alarming. Bacteria are usually heard about in reference to their power of causing human diseases. However, we are not concerned with this type. Bacteria might be classed into three groups somewhat similar to the human social organisations.

Firstly, we have the criminal classes which get all the publicity they want. These are represented by the disease organisms.

Secondly, the class of law abiding taxpayers, who do their job quietly and are consequently overlooked. Corresponding to this group are such organisms as the soil bacteria, whose work is so valuable that if, as some medical men wish, it were possible to kill all bacteria, the soil would become barren in a year or two, and life in the earth would become extinct.

Thirdly, we have the idle rich—persons, and bacteria who, to us, do not seem to have any useful function in the scheme of life, although they doubtless have some use if we could but discover it. To this group belong the tea bacteria about which we know very little at present.

THE NATURE OF BACTERIA.

Bacteria are the lowest forms of plant life and consist of single cells, about one-twenty thousandth of an inch in length. Their small size is balanced by their rate of reproduction. The

average human being takes about twenty years to reproduce his species. Bacteria can do it in half an hour and can keep up this rate as long as conditions are favourable. Ideal conditions could give rise to 60,000 tons of bacteria—descendants from a single cell—in three days, though in practice these conditions never exist.

Bacteria on Tea.

Since the Tocklai Experimental Station was established 20 years ago very little attention has been paid to tea bacteria. Dr. Mann, the first scientific officer, found very few bacteria on tea and concluded that these were all harmful. Using other methods I have found that the tea shoot, even in the field, is literally covered with bacteria. A normal shoot, which is popularly supposed to consist of two leaves and a bud may bear 30 million bacteria. These are isolated by shaking a shoot in water and diluting until a drop of the water contains about 50 bacteria only. Such a drop is then placed in a glass dish and a liquid jelly containing nutrients is added and allowed to set. The individual bacteria being fixed in different parts of the jelly, each reproduces itself until a visible colony is obtained. (At this stage Mr. Benton showed two illustrations. The first picture showed the appearance of typical tea bacteria.) You will see that the bacteria produce small round colonies. These in actual fact are coloured different shades of pink and yellow. Since these bacteria are always present we are forced to the conclusion that their presence is not harmful, and may be beneficial to tea. When a scraping is taken from an infected fermenting floor or part of the machinery in a factory, a different culture is obtained. (Shown in the second illustration.) Here the tea bacteria can be distinguished as small dots while the infecting bacteria are represented by a white spreading mass.

Evidence of Bacterial Taints.

I will now deal with the evidence that bacteria are concerned with the production of taints of tea. The first instance came from a garden in Sylhet. The Brokers reported sour teas and the manager traced a smell to the fermenting floor. This was cleaned and sterilised and manufacture was recommenced but

ILLUSTRATION NO. 1.
Tea bacteria from a clean fermenting floor.

ILLUSTRATION NO. 2.
Taint bacteria from an infected floor.

the first fermentation produced the sour smell again. The floor was therefore relaid. Samples of cement were sent to Tocklai for examination and from these the culture illustrated in the second photograph was obtained. Two foreign bacteria were isolated, one giving a " sour milk " smell and the other a " mousy " smell. The Manager subsequently stated that a "mousy" smell had been evident in the factory for three years. Examination was then made of scrapings from the rollers and the green leaf sifters. These were found to be heavily infected with the same bacteria, the " fur " from the green leaf sifter carrying 30 thousand million bacteria to the ounce. This explained the recurrence of the taint after the floor had been sterilised. A second case came from the Dooars. Here the fermenting floor was found appearance of clean to be perfectly clean and sterile and had the cement. From the roller scrapings the same bacteria were isolated, about 100 thousand million per ounce.

In a third case the manager observed a grey film of "mould" on the fermenting floor during the cold weather, which on examination proved to consist of similar "sour milk" bacteria. In this case no definite complaints of a taint had been made, but comparisons between the quotations for muster samples in Calcutta and the price realised for the invoice in London suggested that the tea had certainly gone off in transit. This is interesting since the presence of bacteria may have been sufficient to produce a "flatness" in the tea without giving rise to an actual taint.

An example of "musty" tea was found to be heavily infected with an organism closely related to the moulds. Here the tea was stored before packing, in a loft which received a discharge of warm damp air from the driers, providing a perfect breeding ground for micro-organisms. The case of a Darjeeling garden came up for examination, in which the usual flavour had been replaced by a "minty" taste. No bacteria were found which could be held responsible for this taint, and it was eventually decided that the taint arose through conveyance of the tea chests in waggons which had recently conveyed cardamon seeds to Calcutta. Since the bacteriological examination had revealed normal condi-

tions, we were compelled to look elsewhere for the source of the trouble, which was located. These few instances are sufficient to show that bacteria may be concerned in the production of taints and also may be responsible for teas which have "gone off" or are "flat" or "not fresh." The object of my short address is to interest you in London in the question, since the broker at home sees most of the game. The long journey undertaken by tea on its way to the London market, under conditions of high temperature, gives favourable opportunities for the development of taints which might not be evident in Calcutta. The planter cannot be expected to detect anything but seriously soured tea, and unless we receive the co-operation of the London brokers, many cases may be missed. It is necessary when undertaking work of this description, to obtain as many samples as possible for examination so that the recurrence of certain bacterial species may be noted. All foreign bacteria found on fermenting floors may not be capable of giving rise to tainted teas and it is only by examining a large number of samples that the fault can be attributed to the right organism. It is here that the co-operation of the London Brokers can help us at Tocklai. If samples of tainted tea are sent to us, or the Calcutta agents are informed, we shall be able to collect such information as will enable us to give definite advice. At present the subject is in its infancy and we can make few suggestions apart from cleaning and sterilisation of machinery. One difficulty with which we are faced is that the bacteria isolated so far form spores which are resistant to heat. Boiling in water for 10 minutes has failed to kill them, and consequently, firing tea at 180° F. may not dispose of the infection. The fact that tea has been found to travel to London safely when packed at 6 per cent. moisture does not preclude the possibility of tea with an infection of souring bacteria, spoiling during transit. Methods of combating the organisms can, however, only be put forward when we have sufficient information of the nature and prevalence of the bacteria with which we are dealing.

The Chairman moved a vote of thanks to Mr. Benton for his lecture which was seconded and carried with applause.

TUNG OIL.*

Particularly referring to the possibilities of production within the British Empire, with a bibliography of the literature.

By

L. A. Jordan, D.Sc., A.R.C.Sc., F.I.C., D.I.C.

Introduction.

Tung oil is an essential raw material of present day varnish manufacture, and in fact its unique properties render it indispensable for certain types of varnish. To-day the position is that we are entirely dependent upon China for supplies, often of inferior quality. In view of the importance of this material to the paint and varnish industry, many have felt the need of freeing the industry from its dependence upon China and China alone in this matter. Plantations have already been started in the United States of America which are developing rapidly with every appearance of a successful outcome. The purpose of this report is to present a summary of information bearing upon the cultivation of the tung oil tree and the manufacture of the oil from the fruits thereof so that a proper judgment may be made as to the feasibility of supplying British needs of tung oil by the cultivation of the trees within the Empire. It will be generally accepted that the development of such a scheme is very desirable so long as there is reasonable prospect of success on an economic basis. One may go further and say that the need for some definite forward action in this matter is urgent.

In China, the tung oil trees (referring to the species *Aleurites fordii* particularly and to *A. montana* in a less degree) occur abundantly and grow luxuriantly, mostly in a region between 26° and 34° North latitude, and in hilly country up to 2,500 ft. in altitude, especially in the upper reaches of the Yangtze valley. *A. fordii* favours the northern and *A. montana* the southern parts of the area, but there is no strongly marked division in the distribution of the species.

*Reprinted from the publication on Tung Oil by Dr. L. A. Jordan, D.Sc., A.R.C.Sc., F.I.C., D.I.C.

Certain areas in the Southern United States of America in the Gulf region lie between the same limits of latitude and seem to enjoy very similar climatic conditions. It is well known that a considerable acreage of land particularly in Florida has been recently devoted to the growing of tung oil trees, and the results of this enterprise on the part of American manufacturers[1] is being closely studied by people interested in tung oil all over the world. Hitherto China has satisfied the world's demand for tung oil, and she will, no doubt, continue to be the chief source of supply for many years to come.[2] It will be some time, under the best conditions, before the American domestic supply, now beginning to develop, can influence the amount of tung oil available for China's other customers. Apart from the difficulties due to the civil war in China and seasonal variations in the crop, the position would appear to be an ever increasing demand for tung oil and a more or less fixed supply. It is generally supposed that in addition to the large export of tung oil there is an enormous internal Chinese consumption, for it is frequently noticed that the Chinese supply of tung oil seems to follow very closely the trading demand and export price values. Assuming that in the near future the American production of oil will cover the regular increase in the American demand, then as the European demand increases it is likely that China may meet it by reducing her domestic consumption so long as prices remain high. At the same time it is certain that there is a limit to the production of tung oil in China, and there is no indication at present of increased cultivation in China taking care of the increased demand. Actually, the trees are not cultivated systematically, for they are hardy, at least when past the seedling stage, and are commonly found on hillsides or in rocky situations and on the poorest of soils unsuitable for ordinary food crop cultivation.

The American Development.

Very soon after the War, American consumers of tung oil appreciated that this oil was becoming more and more a staple raw material of industry, and they realised the danger of absolute

dependence on one source of supply—and that beyond their control. (In 1914 the U.S.A. imported 61 per cent. of the total Chinese export, in 1918 77 per cent., and in 1925 80 per cent., and the American consumption is now 40,000 tons per annum.)[3] They began to study the possibilities of establishing a domestic industry; a period of high prices in 1923 awakened them to the need for immediate action, and the American Tung Oil Corporation was formed in the latter part of that year, with Mr. H. A. Gardner, the Director of the American Paint Research Institute, as Vice-President and General Manager. British paint manufacturers stand to-day precisely where the Americans stood about 1921.

The American Tung Oil Corporation started with a capital of $100,000 subscribed as a co-operative effort among the members of the American Paint and Varnish Manufacturers' Association. The average subscription originally was about $1,200 per member. It should be fully understood that the Corporation was not formed with the sole aim of making profits out of the growing of tung oil trees as a business. The object of the Corporation throughout has been primarily to demonstrate what could be done with tung oil trees as a crop in the hope of encouraging farmers to cultivate the tree on a large scale upon a commercial basis; also it was thought that tung oil plantations on the less profitable sections of average farms in suitable localities might ease the lot of the farmer in the Southern States who, as a general rule, has suffered disappointing years particularly with sugar and citrus fruit-growing.

To judge from the manner in which the work is developing over a very wide area, not only in the Southern United States, but also in Hawaii and the American Pacific Islands, it is clear that the efforts which have been made in this connection in America have received a response from the farmers which fully justifies the experiment.

The state of knowledge as to the cultivation of tung oil trees in 1923 when the American development began, apart from

knowledge of Chinese trees which had been closely studied by various observers in China, was that a few tung oil trees had been successfully grown here and there in various parts of the Southern States of the U.S.A.; the oldest of these trees was said to be some fourteen or fifteen years old at that time.

The Corporation acquired land adjacent to the Agricultural Experimental Station of the University of Florida: in the first instance two separate areas, one of 70 acres and one of 200 acres. The first seedlings were planted out in the spring of 1924, and since then the work has steadily proceeded with ever-increasing confidence and indication of a successful outcome. By 1926, 2,500 acres[4] had been planted up, representing about 200,000 trees. Whilst the first plantations were located in and around Gainesville, Florida, the area of the Southern States in which tung oil has been successfully planted is now very wide indeed. Seedlings have also been planted out in Cuba, Hawaii and elsewhere in the Pacific. Distribution of one-year plants cultivated in nursery centres is made on very favourable terms to *bonâ fide* farmers, and even by the autumn of 1926 the Corporation had in the nurseries half a million seedlings available for distribution. It is clearly the wish of the Corporation, and also of the Government Department concerned (the Department of Commerce) to do everything possible to stimulate the independent planting of tung oil trees. In regard to the technical requirements of the enterprise the Corporation has throughout enjoyed the active co-operation and help of the Florida State Agricultural College, whose officials have studied the problems of the best cultural conditions for the tung oil trees and generally superintended the experimental work.

In the Annual Report of the Corporation for the year 1927, reference is made to the increase of capital to $150,000 and the following words are very significant as to the progress made:

"The development of the groves at Gainesville during the past year has been very gratifying, and a substaintial crop of

fruit was obtained (approximately 16 tons). This fruit is being shipped to northern points for experiments in hulling and crushing, so that final data may be obtained on the best types of machinery for this purpose. The information so obtained will be available to those interested in designing an oil mill in the Gainesville district.

" Although northern Florida experienced early in January 1928, the coldest weather in twenty years, a careful examination of our trees indicated that no damage was done to them although considerable damage was done to citrus trees in the same section. It is therefore anticipated that there will be a still larger crop of fruit in the fall of 1928, with steadily increasing yields in following years. The frost damage to citrus trees will probably result in diverting the interest of the agriculturist in northern Florida from such trees to tung oil trees and may thus have a beneficial effect in so far as our venture is concerned.

" The interest in the cultivation of tung oil trees is steadily increasing on the part of large land holders . . . .smaller quantities have been sold from the nurseries at Gainesville for planting by many individuals. In addition, several hundred pounds of seed have been shipped to New Zealand, Jamaica, the Virgin Islands, the Philippines, and to England, where British paint and varnish technologists have become interested in the possibilities of developing tung oil groves in their colonial possessions. The prospects are that there will be a heavy demand next fall for tung oil seedlings, and . . . ."

Substantial further progress was indicated in the President's Report for the year 1928, of which the following excerpts are particularly interesting, especially those concerning seed crushing experiments.

" Estimates have been made which indicate that up to the fall of 1928 the acreage of tung oil planted in Florida as a result of the educational work of the American Tung Oil Corporation

may aggregate approximately 4,000 acres. Further indications are that during the winter of 1929 an additional 1,000 acres of tung oil trees may be planted in the State of Florida. Several plans have been put before the Corporation by large landowners to form separate individual corporations for the planting of tung oil groves on a large scale. . . Manufacturers consuming large quantities of tung oil in the production of varnishes and insulating compounds, who have viewed the operations at Gainesville, have been very much impressed, and have considered the possibilities of planting extended acreages to safeguard their own requirements.

" During the early part of 1928 there were crushed 30,000 pounds of seed in an experimental way to determine the best types of machinery for the purpose. Most of this seed was produced from our own groves, although a portion was purchased from other American planters. Previous to this work, over 100 small crushing tests and analyses of seed were made in the Scientific Section laboratories, and Mr. Gardner spent several weeks in arranging for the carrying out the large size crushing tests.

" Some of the methods of producing oil from the seed were not satisfactory and the yields obtained were not as great as they should have been. The best results were obtained with the Anderson expeller which was adopted as the equipment for the mill that has been erected at Gainesville. Several thousand pounds of the seed were used in experiments with extraction apparatus, but unsatisfactory results were indicated with these processes. The oil obtained was distributed for test purposes among about eighty varnish manufacturers. Reports on these samples have come in and practically every one of these reports indicates the superiority of the American grown oil over the foreign product.

" A nursery of about ten acres was developed during 1928. Unfortunately the rainfall during the summer was greater than

for many years past. Because of inadequate drainage, many of the seedlings were affected by this excessive moisture. A few thousand, however, came through in good shape and are being distributed to prospective planters. It is the plan during 1929 to increase the nursery to 30 acres and to provide proper drainage for it."

In January 1929 the first large scale tung oil mill came into operation, capable of expressing about 50 gallons of oil per hour[5]; this may be said to mark the beginning of activities on a real commercial scale. As yet only a small proportion of the trees are of any age to bear fruit, but if expectations are realised, and there seems to be nothing to stop them being realised, the yield of U.S.A. produced oil should be several hundreds of tons this year and henceforward as the trees come into bearing the output should increase rapidly. The planted area of trees in full bearing necessary to supply the present American demand has been variously estimated[6] but is probably about 100,000 acres.

Quality of American-Grown Tung Oil.

A most important feature in the study of tung oil is the fact that it has always been liable to heavy adulteration. It is generally admitted that adulteration with soya bean oil, rape seed oil, tea seed oil, perilla oil, ground nut oil and sesame oil is still practised to a great extent. One of the most interesting points of attention about the American production of this oil is the prospect of securing a really pure oil extracted under clean and proper conditions. Apart from the question of adulteration, the Chinese methods of roasting the seeds and pressing the oil are so primitive that the oil is often much darker in colour and more variable in its characteristics than it need be.

The following values have been reported[7] for various samples of oil obtained by laboratory expression from small lots of American grown seed as early as 1924.

The high gravity, high refractive index, low acidity, low heat test and excellent colour are noteworthy.

	Cold pressed Florida No. 1.	Florida No. 2	Cold pressed Alabama No. 3	Hot pressed Alabama No. 5	Cold pressed California No. 6
Appearance and colour ...	...	All pale	and clear.		
Spec. gravity at 15·5°C. ...	0·941	0·944	0·942	0·941	0·931
Acid number ...	0·5	1·0	1·2	1·36	0·64
Saponification No. ...	193·8	194·4	191·6	191·5	192·3
Refractive index ...	1·519	1·5175	1·5187	1·5188	1·5155
Iodine number ...	166·0	161·0	166·8	166·1	165·0
[9] A.S.T.M. heat test ...	10¾	9⅝	10½	11	10—12 Stored seed over 1 year old-abnormal

Samples of tung oil from the large scale crushing experiments carried out during the winter 1927-28-29 have been variously reported[8] on as follows :—

Appearance and colour	...	Straw colour—extremely pale and clear
Specific gravity at 15·5° C.	...	0·938—0·941
Acid number	...	0·3—1·3
Saponification No.	...	190—194.
Refractive index at 25° C.	...	1·5175—1·5185
Iodine number	...	159·2—167·8
9A. S. T. M. heat test	...	7¾—9¼ mins.

Three different samples of American grown tung oil have come into the possession of the Research Association and these analyse as follows :—

	I[10]	II[11]	III[12]
Colour	Very bright	and pale.	
Specific gravity 15·5°C.	0·9407	...	...
Acid number	1·3	0·17	0·25
Saponification No.	192·7	...	...
Unsaponifiable matter	0·46	...	...
Iodine number (Wigs)	164·9	166·1	166·0
Refractive index at 25°C	1·5183	1·5175	1·5173
Heat test	11 mins.	...	11 mins.

During 1928 the American Tung Oil Corporation distributed a considerable weight of oil to varnish makers for large scale varnish-making tests. It is quite clear from the report[13] of the results obtained that American oil is entirely satisfactory and

has generally been found superior to imported oil. To quote examples, one maker reported a slight improvement in colour of his finished varnish when made with American grown oil; another reported that American oil gave a faster bodying action in the kettle, producing a paler, clearer varnish with a somewhat faster and harder drying film and with better hot water resistance; another reported that the American oil made tougher and more elastic varnishes with better water resistance, etc., etc.

There seems no doubt about the fact that American grown tung oil will be acceptable to the industry. At no time has a sample of oil been found to give abnormal properties; such changes in the characteristic values and properties as have been noted are entirely desirable and probably indicate the extent of previous adulteration and/or decomposition due to faulty and negligent handling of the nuts prior to and during expression of the oil.

Chinese Supplies.

During the War, there was a great increase in the demand for tung oil, and whilst conditions and price values have from time to time varied considerably since then, the tendency is for the European demand to increase steadily. A study of the available statistics shows a remarkable increase in recent years in the amount of oil taken by the smaller consuming countries with British consumption steady since 1923. It would appear as if the domestic consumption of tung oil in China is sufficiently large and elastic to permit of supplies being absorbed or relaxed according to the export demand, at least up to a point, but as has already been stated, there is little or no prospect of increased cultivation of tung oil trees in China in response to the increased demand for the oil. It has been said that the consumption of tung oil in China greatly exceeds and may be double the total export, but this reservoir of oil is certainly not available except at good prices. It is evident that an increasing world demand must encroach more and more on the stocks of material normally reserved for domestic use in China with a consequent upward

tendency in price. The disturbed state of the country can only accelerate this effect since one would expect supplies to shrink rather than expand. Under the best conditions the difficulties in collecting the nuts, for the tree is gregarious in habit, expressing the oil by native methods, and transporting the oil from the interior to the ports are many; years of civil war cannot have made these difficulties any easier.

In spite of the labour and the large percentage of waste involved in the operations, tung oil is regarded as a most profitable crop by the Chinese. In this very fact lies the strongest argument for presuming that scientific cultivation of the trees in plantations with adequate machinery for crushing and collecting the oil is bound to succeed. The systematic cultivation of the tung oil tree may well follow, though on a smaller scale perhaps, the example of rubber. To-day it is a fact that rubber grown in its true home, the Amazon basin, although there are countless trees available, cannot be produced at the cost of plantation rubber, because the method of ordered scientific cultivation of the tree and harvesting of the product is more effective than the causual collection of the jungle product.

Further, as already remarked, the Chinese have ever been notorious for adulterating tung oil. That American paint manufacturers were concerned about the quality of the Chinese supplies of tung oil is shown by the fact that their Association in 1927 appointed a Committee to work with the chief importers in organising and handling supplies of oil. As a result of this work trading rules have been developed by the Oriental Oils Association, which might well be adopted[14] generally. It is the aim of this Oriental Oils Association to maintain a standard of quality if possible, and recently it has been reported[15] that from one reason or another better quality tung oil is being exported from China to the U.S.A. than ever before, and further, prices have been much more steady. This rather suggests that even in spite of civil disturbances there is someone taking notice of and profiting by what is happening in America.

Empire Cultivation Prior to 1927.

Tung oil was first known outside China about 1760. It was first introduced into the U.S.A. in 1896, into Germany in 1897 and soon after into England. Characteristically there was less interest shown in the oil in England than elsewhere and it may fairly be said that many varnish manufacturers " discovered " it during the War, when special water resisting varnishes were badly needed for aeroplane work.

The need of the moment brought the question of tung oil into prominence. In 1915, Wilson[16] stated as a result of his personal explorations in China and investigations elsewhere that *A. fordii* should be easy of cultivation in South Africa East Africa, Australia, Algeria and Morocco; early in 1917, on the recommendation of the Raw Materials Committee of the Imperial Institute, growing experiments were started, which have been continued, at intervals since, in India, Ceylon, Malaya, Burma, Kenya, Tanganyike, Hong, Kong and South Africa. The amount of seed availiable was small, and the number of trees forming the subject of these growing tests was smaller. It is not surprising therefore to find that the results of these experiments considered alone are frequently disappointing. Fortunately there are reasons for supposing that some of the disappointments were probably due to the immediate local conditions rather than to the climate of the districts generally, for the young trees do not always seem to have received the special care and study that they needed at the nursery stage. The American development has proved the paramount importance of nursery care if the cultivation of this tree is to be a success.

Of this early work, trees of the 1922 planting at an altitude of 5,500 ft. in Kenya have survived, and sameples of the fruit from them were forwarded to the Imperial Institute during 1927. These seeds gave a similar yield of oil and of the same character as did the Chinese seeds from which they were gown.[17]

There is no information published about the South African experiments, although individual trees are known to be living and doing well at Salisbury, Rhodesia.

The records relating to India refer to experiments at Dehra Dun. In 1924 trees of *A. fordii* were fruiting at six years old, but the seed germinated badly, and consequently there was no development taking place. There are probably other places in India at least equally suitable climatically for the trees, but there is no evidence that the study has been sufficiently systematic or the operations spread over a sufficiently wide area for any judgment to be made on the question. The Indian Forestry Records[18] seem optimistic about the prospect of cultivating *A. fordii* in India because *A. montana*, the less hardy tree, grows in parts of Burma at an elevation of 1,500 ft. It is clear that the cultivation of *A. montana* within certain restricted areas of the Shan State should not be difficult, but *A. fordii*, with its higher range of elevation, should be more suitable for general cultivation.

Reports from Ceylon and Malaya indicate no prospect of successful cultivation of *A. frodii* on a commercial scale, but the experience with *A. montana* was a little more promising.

It was proposed in 1925 to establish small plantations of *A. montana* and *A. fordii* in Hong Kong. These trees, mostly *A. montana*, are not yet old enough to fruit.

Fortunately there is much more information available about the experiments in Australia where there are something like 1,000 trees under plantation in New South Wales.[19] These trees have been planted at intervals mostly since 1919, and sufficient oil has been produced to enable a study to be made of its properties. There is an admirable report[20] on this subject which concludes with the statement. "The author is satisfied that the oil from Australian grown trees of *A. fordii*, when obtainable in quantity, will be quite satisfactory in technical practice and yield varnishes equal to those manfactured from imported oil."

The following is a summary of the results obtained :—

Date	1923	1925	1925	1925	1926
Sample ...	...	Solvent extracted	Cold expressed	Solvent extracted	...
Specific gravity ...	0·9415 at 15·5°C.	0·9322 at 20°C.	0·9392 at 15·5°C.	...	0·9397 at 15·5°C.
Acid No. ...	1·1	0·6	4·48	1·5	1·8
Saponification No. ..	195·6	186·4	192·0	195·8	183·3
Refractive index ...	1·5160 at 25°C.	1·5168 at 25°C.	1.5150 at 25°C.	1·509 at 40°C.	1·5160 at 25°C.
Iodine No. ...	167·5	160·5	164·3	165·1	166
A.S.T.M. heat test ...	...	11½ mins.	11 mins.	...	10 mins.
Melting point ...	...	46·5°C.		30·0°C.	...

Yield of fruit from tree—not recorded.
Yield of seed on fruit—approximately 53 per cent. by weight.
Yield of oil on seed—from 43 to 54 per cent. by solvent extraction.

It is also quite clear that the Superintendent (19-8) of the Botanic Gardens, Sydney, was an enthusiast on the subject of tung oil. He wrote an interesting article[21] in 1918 describing the beginnings of the matter. The first seeds of *A. fordii* were planted in 1913, but only one germinated. Care was taken of this one plant, for the first eighteen months particularly, and three years afterwards it began to fruit. In 1918 it yielded 1½ bushels. In the meantime other seed was coming forward, and it was soon concluded that the tree would grow almost anywhere in New South Wales except in the very coldest districts. This report also states :—

" It is the purpose of the Director of the Botanic Gardens, with the approval of the Under-Secretary and Director of Agriculture, to distribute one-year plants (grown in the trial ground of these Gardens) to all the Experiment Farms throughout the State, to be grown under orchard conditions. After such a practical test it should not be difficult to encourage private individuals to plant under orchard conditions also. . . in the many large uncultivated places in this State, such as the arid area of the Murrumbidgee irrigation district, the uncultivated slopes of the Hawkesbury ranges and the Kurrajong, it will be tested to see if it will pay to plant 20 feet apart and cultivate on orchard lines."

Empire Cultivtion since 1927.

The need for a close study of the prospects of tung oil plantations within the Empire would be clear even if the political situation in China were normal. The situation being what it is the need may be said to be urgent.

One of the first duties undertaken by the Research Association of British Paint, Colour and Varnish Manufacturers was to review the situation respecting the Empire production of tung oil. The Director was requested to prepare a paper collecting all the information available on the subject of tung oil production. This paper was published privately by direction of the Council of the Association; over 600 copies have been sent to interested individuals in all parts of the Empire all over the world. Thus this matter has appeared in the programme of work of the Research Association from the beginning, and it is a fact that the emergence of the Industry, through the medium of the Research Association, as an active supporter of plans for the development of tung oil plantations, has done much to stimulate an extraordinary degree of interest and enthusiasm about the subject in all parts of the Empire. This industrial support during the last two years has been the primary motive force; it should be recognised and encouraged as the corner stone of the whole scheme.

Fortunately the nature of the problem is such that something definite can be achieved within a comparatively short term of years; further, development work of this nature would be of lasting benefit to those parts of the Empire which proved suitable to the growth of the trees. A great deal of careful experimental work is required before such a matter can be brought to full fruition, but we have the benefit of the experience gained through the American experiments where the trees have been grown and oil produced almost on a commercial scale within six years. There are undoubtedly parts of the Empire climatically suitable for the growth of tung oil trees, and where the value of the land and the cost of native labour will ensure a relatively greater margin of safety to this enterprise than even in America.

The Research Association decided to do something; with funds subscribed by the Industry, the Association purchased 700 lbs. weight of selected seed of *A. fordii* of the 1927 American crop and distributed it to privately owned farms and estates, Government agricultural stations and Forest officers over the widest possible area. The General Manager of the American Tung Oil Corporation has throughout rendered the greatest assistance to this development work, not only with seed, but advice, for the American view is that beyond a certain point they must ultimately look to British Empire production to augment their own supplies.

The distribution of this seed was effected with the help and advice of Sir William Furse, the Director of the Imperial Institute, and Dr. Hill, the Director of the Royal Botanic Gardens, Kew, whose co-operation throughout has been of the greatest value. Also during 1927 various officers of the Agricultural Research Conference became interested in the revived tung oil projects. In particular the Director of the Amani Institute at Tanga, Tanganyika, offered to raise plants from our seed and establish a nursery centre for the whole of Middle East Africa. In the winter of 1927-28 there was sent to Tanga 254 lbs. of African seed of *A. fordii* equivalent to 50,000 plants if only half germinated, and a similar quantity of seed of the 1928 Chinese crop has since reached there, in this case of both *A. fordii* and *A. montana* species. It was thought that Middle East Africa, from the variety and range of climatic conditions offered especially in Kenya, would be a most suitable area : in fact, there is a strongeer *primâ facie* case for growing *A. fordii* successfully in this area than almost anywhere else in the world. Considerable development is already apparent in this area as the result of this work ; plants have been distributed to the farming community and are growing at a variety of elevations and under different conditions in all likely places over a wide area of Middle East Africa. It is as yet too early to expect more than preleminary reports as to the prospects of the young plants but on the whole these reports are encouraging, except for a plague of locusts which recently descended upon Tanga and did great damage to crops generally.

As far as Africa is concerned, tung oil plants of our 1927 seed are now being watched everywheere from Kenya to the Cape—in Nyasaland, Tanganyika, the Rhodesias, Transvaal, Natal and Cape Province, and in Nigeria. A further distribution of 1928 seed has recently been made from Kew.

Any *bonâ fide* farmer who can show that he has a reasonable chance of raising the seed and is prepared to look after it, and report as to his experiences with it, has been given seed, anything from 5 to 20 lbs. or so according to curcumstances.

The seed in the hands of the agricultural stations will serve as a check on performance in specific areas, but whilst everything is dependent upon the goodwill of the agricultural officeers in advising their local growers, it was felt that as no commercial development is possible anywhere except through the farmer, the sooner the farmer was induced and helped to start in on the job of becoming acquainted with the species the better. As a result of this policy the Research Association received, and continues to receive, letters asking for the pamphlet and seed. Such applications are always responded to and seed sent if there is the remotest chance of the crop being successful in the place indicated. The present need is to collect information and that information is beginning to come in. The man who sends in reports will get more seed provided the reports are favourable. No reports—no seed. Gradually the area of distribution will be narrowed down and increasing quantities of seed passed into selected areas so that commercial plantations may be realised in the most favourable regions in the minimum of time.

To return to the areas to which seed has been sent, parts of the Indian Empire appear to be especially promising. Seed was sent to the Nilgiri Hills region of Madras, the Malwa plateau of Central India, Behar and Orissa, Bengal, Assam, Malay, Ceylon and Burmah, where *A. montana* is indigenous. Of these areas about half only have so far made any report. The Lac Research Institute in Behar and Orissa, and the Central Indian area report rapid growth and good germination with the seedlings making

progress without set-back, but the most encouraging reports of all have come from Assam. In all there were seven separate tea growing estates in Assam which received seed. All of them report approximately 50 per cent. germination with strong plants, very fresh in appearance and doing well except in one case where the trees although growing rapidly were eaten by crickets. One estate reported trees averaging 4 ft. high at four months old after transplanting: another reported that trees varied from 18 ins. to 6 ft. high with branches 18 ins. long and a 3 ins. girth at six months old: three of the estates reported 6 ft. trees which is a remarkable rate of growth from seed in one season.

The tea planting districts of India and Ceylon will receive special attention in the near future.

Cyprus is an area to which considerable attention has been paid, and furnishes an excellent example of what can be done with care. Some twenty-four separate nursery lots were started on the island, but although germination was fairly good (40-55 per cent.) the infant death rate was rather high so that after six months only about 50 per cent. of the original plants were alive. This was thought to be due to sowing at the wrong season and the prospects are now brighter.

Seed was also sent to the West Indies, Antigua, Montserrat, St. Kitts and others of the Leeward Islands, Jamaica, Bermuda, Palestine, Australia, and New Zealand.

There is nothing exceptional to report about the smaller places mentioned except Jamaica which is definitely negative, and Bermuda, where, although growth is good, there is not likely to be room on the Island for such a crop.

As already stated, much good work has been done years ago in New South Wales and this work is bearing fruit.

A considerable quantity of seed was sent to the New Zealand State Forest Service and to the Agricultural Department in the North Island. Since then there have been repeated demands for more seed and a widespread distribution is going on. Owing to the change of seasons the 1927 seed could not be sown until

October 1928, so that reports could scarcely be expected as yet. There is something moving in New Zealand for the American Consul recently reported[22] that a syndicate of local agriculturalists in the North Island was being formed to place 2,000 acres under tung oil in the Helensville district, which is said to be eminently suited for it. The nursery was being started with a nucleus of 1,000 plants.

A second report[23] came from other sources that British capitalists were proposing to develop 8,000 acres in Auckland province with tung oil.

During the last year the Director of Forestry to the New Zealand Government resigned his post to become Technical Director of Queensland Forests, Limited, who are energetically preparing to develop tung oil plantations in North Queensland. This company report 99 per cent. germination of our 1927 seed with plants growing vigorously and 12 ins. high at three to four months from time of sowing the seed. This rate of growth was most unexpected, and so far the results are an unqualified success.

Such is a brief record of the recent work, which is clearly worthy of the utmost support not only by the Industry but from all interested in Empire development. Financial assistance for the active prosecution of a development of this character appears to be a matter for which the Empire Marketing Board was expressly designed and for which it is eminently suitable. The correlation and direction of these activities over such a wide area is a matter calling for considerable powers of organisation for there is much more in the work than distributing seed and waiting for results. It should be someone's duty to watch the economic aspects likely to affect development in specific areas: problems affecting transport of the fruit or seed must be decided before any decision can be taken on the question of crushing the seed locally or in England: the value of the cake and other residues must be determined: a watch kept upon the possibility of variation in the characteristics of the oil as influenced by climate, fertilisers, etc.: the possibility of developing special

varieties of the trees is a most important matter requiring attention, corresponding to the development of the " multiple cluster " variety in America : there are numerous other problems relating to tung oil, all of which should be investigated as part of a well considered and unified scheme of work.

All these matters require single executive authority with the necessary driving force—financial and otherwise—if the schemes are to be put through.

There is the record of the American work—a splendid example of what can be done. To-day the Empire is six years behind American in this matter. That is, six years lost during which time American varnish manufacturers will have the use of oil of such a quality as is not within the knowledge or experience of varnish makers in this country.

On April 15, 1929, a sub-committee of the Oil and Oilseeds Advisory Committee of the Imperial Institute was formed to prosecute the tung oil development work.

Botanical Relationships.

So far, reference has only been made to "tung oil," referring to the product of the two species *Aleurites fordii* and *Aleurites montana*. The terms "Chinese wood oil" or simply "wood oil" are commonly used for this oil in Europe and America, but as the latter term especially lends itself to commercial misrepresentation its use is to be deprecated.

The botany of the *Aleurites* species (*family Euphorbiaceae*) was in great confusion until Wilson[16] made a close study of trees growing in China, and there is no doubt now that the bulk and the best of Chinese oil comes from *A. fordii*. Actually there are two closely related species, *A. fordii* and *A. montana*, which have slightly different geographical habitat, the first belong principally to Central and Western China, whilst the second, the less hardy plant, is found more to the south.[24] *A. montana* is far less numerous than the other variety, and its oil is not sold commercially as such; probably it is worked in with *fordii* oil which is estimated to form 90 per cent. of the output.

A. montana, although somewhat less hardy than *A. fordii,* is a very quick growing tree, and experiments are in hand at the University of Florida in cross-pollinating blossoms of *A. fordii* with pollen of *A. montana* whence a strain of seed might be expected which would show very rapid growth and yet retain some of the distinct properties of the *A. fordii.*

Another member of the family is A. cordata which grows extensively in Japan, and yields a product known as Japanese wood oil which, however, does not polimerise like true tung oil. It is quite a distinct product differing from tung oil in its chemical and physical properties, notably in its lower specific gravity and lower iodine value, but owing to the confusion in the botanical classification which existed prior to Wilson's investigation, some records relating to A. cordata really apply to A. fordii.

Another important member of the same family is *A. triloba* or *mollucana,* the source of candle nut or lumbang oil which, although it is very useful, does not conform in its characteristics and properties to tung oil.

Manner of Growth and Cultivation.

General.—The tung oil trees *A. fordii* and *A. montana* are very ornamental in character and rapid growers producing fruit in favourable circumstances in and after the third year. In China they generally grow to 20 or 25 ft. in height with a trunk of about 10 inches in diameter. Some are said to reach up to 50 or 60 feet in height, with a canopy 60 ft. in diameter, but such trees are exceptional.

Tung oil trees have a low branching habit of growth, and unless pruning is practised they seem inclined to produce a straggling head rather than a straight, well pronounced central trunk. The trees are said to require the minimum amount of fertilisation, cultivation and general care. They are deciduous, shedding their leaves in October and November. The leaves are large, dark green in colour, and more or less heart shaped. The flowers, produced before the leaves, are white with pink centres

and yellow stamens on the male blossoms. The clusters are drooping and the foliage dense. Each cluster is made up of one or more female flowers surrounded by male flowers, there usually being but one female flower to the cluster. Some years ago in America certain trees were noticed which had two or three female flowers to each cluster. It is hoped that selected seed of this type known as "multiple cluster" seed will transmit this characteristic and lead to the development of a special variety which may be expected to crop more heavily than the ordinary tree.

The blossoms are very sensitive to early spring frosts and have not infrequently been killed in the regions north of Florida when planting trials have been made there. The established *A. fordii* is hardy enough to resist occasional frost, but the young tree is not likely to be successful in areas subject to frost.

The fruits are about the size and appearance of a russet apple being first a dark olive green turning to a deep brown as maturity is reached. When fully ripe the fruits fall and in due course burst open from the base upwards, exposing three, five, or even seven seeds which resemble the triangular Brazil nut in shape and colour, but are much smaller. The fruits ripen at approximately the same time in both China and America, that is in October. In China it is usual to knock the fruits off the trees before they are perfectly ripe. The husks are then removed by parching the fruit in iron pans over a fire or by collecting the fruit in heaps and allowing fermentation to take place to loosen the husks. Alternatively the fruits may be harvested at leisure after having fallen to the ground as they do not deteriorate through lying on the ground for a few weeks, and they are not eaten by cattle because of the disagreeable taste. The seed proper, after being removed from the husk, can be stored in any dry place for an indefinite period. However, if the seed is to be used for planting it should only be removed from the husk immediately before planting, and should not be carried over from one season to another. Seeds should be planted during the winter following the autumn in which they drop from the trees.

The age when the tree begins to fruit depends to a considerable extent on the richness of the soil, the amount of rainfall and the treatment it has received during its early years. As found in some localities in China, trees fruit at three years, but usually the fourth or fifth year brings the first commercial yield of fruit, after which the yield steadily increases up to the ninth or tenth year. The useful life of the tree is at least 25 to 30 years.

Pests.—Tung oil trees grown in America have so far been relatively free from insect pests or disease. Apparently the original seed which was brought from China to the U.S.A. in 1905 did not bring with it any of the insects or diseases which may be expected to affect the tree in its native habitat, for no growing plant of any kind is known to be entirely immune to the attacks of parasites. In consequence of this happy condition, it is now the policy of the Agricultural Experiment Station, University of Florida, not to tolerate the importation from China of any further quantities of seed of *A. fordii* for planting purposes owing to the fear of securing, with such importations, destructive diseases which might seriously affect the future of the American industry. So far the American industry seems to have escaped any serious infection. It is recorded that only one root parasite, the nematode, and two species of scale insects have been found attacking the trees; the nematode parasite causes the trouble known as root knot, and is known to attack a great number and variety of trees and plants though some which are subject to heavy attack in the Southern States are, by using proper precautions, still grown for profit. The very fact that the tung oil tree's susceptibility to root knot is known makes it possible to take precautions against this trouble.[25]

The two scale insects found on tung oil trees are the cotton cushion scale (*Icerya purchasi*) and latonia scale (*Aspidiotus latonia*). The first form is commonly found on citrus trees growing in the same vicinity in Florida, and the second in plums and pines. These pests are not considered to have great importance as they can be easily controlled by spraying or scrubbing.

A scale insect pest was reported in the New South Wales (1918) reports, but it was completely destroyed by one spraying with "red" oil (1 in 60).

Rainfall and Temperature.—A main consideration in the culture appears to be the absence of frost and a sufficient rainfall, which should not be less than 30 ins. but preferably 50 or even 70 ins. The *A. montana* species requires rather more rainfall than *A. fordii.* According to Wilson, in China the tree requires a minimum rainfall of 70 cm. and he states that the tree luxuriates at Ichang where the rainfall averages 75 cm. most of which falls in April, July and August.

Also at Ichang the climate is rather one of extremes. The summer is tropical, the shade temperature ranging from 90° to 110° F. The winter is generally cold with much snow though the temperature seldom falls as low as 28° F.

Soil.—Certain tung oil trees at Tallahassee[26] have apparently done well in heavy clay soils. At the Experimental Station at Gainesville, the trees have grown well upon a sandy loam, a soil that is very sandy and naturally rather deficient in plant food.

Gardner[27] summerises the problem of the attributes of the soil in the following words :—

" Tung oil has been tried on almost every type of soil, and has been found to grow on practically any soil which is slightly acid with plenty of moisture but still well drained.

" Apparently the ideal soil is a sandy soil or sandy loam which is underlaid with clay three to eight feet down. This type of soil can be usually drained easily but remains fairly moist. This does not mean, however, that the tung oil tree cannot and is not being grown successfully on other types of soil. Tung oil trees in Florida have grown on land that ranges from almost pure white sand to a heavy clay loam, with excellent growth and yields on all. The observations show that slightly acid soil, well drained but with plenty of moisture, is safe to use for tung oils Alkaline earth is fatal to the growth of the tree."

According to Wilson, in China the tree " appears to have no strong predilection in the matter of soil, and grows equally well on conglomerate, hard limestone, sandstone or sandy clay. It is essentially a hill-side tree, thriving in the most rocky situations and in the poorest of soils."

Propagation.—So far as is known, the principal method of reproducing the tung oil tree is by seed propagation, although it has been determined that the trees can be readily budded and grafted with tung oil seedlings as stock.

Planting.—In Florida the best time to plant is in middle February when the soil is warm and maximum growth can be expected. Great variation is found in germinating power, particularly. Some sixty days are usually required for germination, but seed has been known to lie in the ground three months before sprouting.

Single seeds (not the whole fruit) should be planted three or four inches deep and from eight to twelve inches apart in the nursery row. If in heavy soils the seed should not be planted at a greater depth than two inches.

Nursery rows should be not less than three feet apart to permit of ample cultivation between them.

Fertiliser is not required at time of planting.

In China, two seeds are planted in a dug over spot 3 to 5 feet in diameter, and the soil kept in loose condition. If both seeds germinate one is removed. Transplanting is not generally very successful.

Under favourable conditions in China plants will make three feet growth in the first season.

Site of Nursery.—A well-drained but fairly moist location should be chosen. The moisture content of the soil, particularly during the spring dry season, is of prime importance, as if the seedlings are supplied with adequate moisture during this time they will not suffer from a set-back in growth which would be caused by droughty conditions. At the same time, the soil should

be well enough drained that no water will stand between the rows for any length of time during the summer rainy season, which has a scalding effect on the young seedlings.

Nursery Cultivation.—Regular shallow cultivation should be given throughout the growing season so that a good dust mulch is always present and the nursery free of weeds or grass at all times. Because of the shallow rooting habit of the plant, deep cultivation should be strictly avoided after the first few weeks.

Transplanting.—When the time comes to transplant trees from the nursery to the grove, the methods commonly used in transplanting fruit trees are employed. The work should be done whilst the trees are dormant, and care should be taken to prevent injury to the root system.[28,29]

As with all plants, exposure to sun or wind should be avoided, and at no time should they be allowed to become dry. Trees should be planted at the same depth as they stood in the nursery row. Deep planting is highly injurious. When seedlings are transplanted they should be cut down to a stub 12 or 14 ins. above the ground. When established, no further pruning of young trees seems to be needed other than cutting off the tip of the plants; this may be done to cause more lateral branching close to the ground. In this connection the question of the distance to plant out the trees presents itself.

Orchard Distances.—The best size ordinarily attained by tung oil trees in China is about 25 ft. by 20 ft. spread under ordinary circumstances. They are frequently found about 11 ft. apart. Growing the trees under orchard conditions, it would seem that 20 ft. each way would be sufficient space for the proper growth of the canopy. However, as it seems that the cultivated plantation trees in Florida bid fair to exceed in size the average Chinese tree, distances of 25 by 25 ft., 25 by 30 ft., or even 30 by 30 ft., are suggested. Gardner suggests that trees should be planted in parallel rows, 12½ ft. between trees in the row, and 30 ft. between the rows. After the seventh year alternate trees should be removed which will leave 25 ft. between two

trees in the same row and each tree will be 32½ ft. diagonally removed from its nearest neighbour in adjacent rows. It is calculated that the extra yield of fruit before the alternate trees are removed is sufficient to justify this practice. This arrangement finally bears 60 trees per acre.

Fertilisers.—The fertiliser needs of the tree have not been fully determined except to prove that young trees respond quickly to light applications of nitrate of soda or of Peruvian guano up to 1 lb. per tree. Cultivation between the trees by leguminous cover crops is recommended to keep the soil rich and moist.[30]

The General Manager of the American Tung Oil Corporation has recently communicated the following details of experience with different fertilisers :—

" Fertilisers used should be chiefly nitrogenous, such as nitrate of soda, cottonseed meal, blood, tankage and so forth. Both stable and chicken manures may be used, but the latter must be applied sparingly. As soon as the seedlings have attained a height of a few inches, a complete fertiliser may be applied, using from 5 to 8 per cent. of ammonia and about 8 per cent. of phosphoric acid. Probably little potash is needed at this time. As nitrate of soda is very soluble and leaches readily, it should not be used solely as a source of ammonia in complete fertilisers, using instead some organic source for at least part of the ammonia content. At least three applications of ammonia should be given prior to July 1st. These need not be large, but a supply should be readily available to the plant at all times to insure a maximum growth. A total of 200 pounds of nitrate of soda per acre should be sufficient for the season's growth. Probably about a half-ton of a complete fertiliser can be used to advantage, but the amounts necessary to secure maximum growth will depend very much on the fertility of the soil in question as well as the amounts of moisture present in that soil during the whole of the growing season."

Fencing.—The fencing of young plants against wandering cattle is essential in the early stages of growth.

Crushing Experiments.

Such information as is available on the subject of crushing tung oil seed in China indicates that the husks are first removed by parching the fruits over a fire in iron pans (18 in. diam.), or by allowing the husks to ferment away from the seed, the fruits being piled in heaps for this purpose. The seeds are then ground to a meal in stone mortars (about 3 ft. in diam.) using bullock power. The meal is then heated, mostly by steam, and placed in wedge presses. The oil is finally strained through silk or grass cloth. Sun curing the kernels before crushing is said to produce a light-coloured oil, whilst extreme heat or excessive fermentation under bad conditions yields a dark coloured oil. It is also usual to press twice, the once pressed meal being reheated more strongly than before. The first cold-pressed oil is said to be mostly exported, and to dry more rapidly than the second hot-pressed oil which is retained for domestic consumption.

Attempts have been made to establish a tung oil testing centre on European lines at Shanghai, but there has always been difficulty in obtaining a full supply of seed. The Chinese much prefer to crush the seed locally, transporting only oil.

The first laboratory pressings of American grown seed were made in 1924, using an Anderson expeller and an ordinary hydraulic press.[31]

It was found that an extremely light-cloured oil could be produced if the seed had been properly dried, either by the sun or by exposing the seed upon flat trays in heated rooms. On the other hand, if seed still contained moisture, a very dark-coloured oil resulted. This was found to be due to the high moisture content of the shells of the seed which resulted in slimy matter being carried into the oil during pressing. It was also found that the heating of seed containing moisture contributed to the development of colour and to the development of acidity through hydrolysis.

When white meat was picked from the shells, a very bright and light coloured oil almost water white was obtained, but to follow such a course on the large scale is impracticable. Attention is also drawn to the very low acid value of oil produced from American seed. It is believed that the high acidity of foreign oil is due to improper storage of the seed. The development of enzyme action during storage of the seed in moist places, or the hydrolysing effect of water in stored oil before shipment and the setting free of fatty acids would be contributing factors in this direction. Everything points to the need for effective drying of the seed before storage and before pressing.

Early in 1928 large scale experiments[32] were undertaken in hulling, separating and expressing oil from from the 1927 crop of fruit. Some 14 tons of fruit were available for these tests. Decortication was successfully accomplished in a 24in. disc huller[33] and a separator. In this operation the whole fruit was delivered to the disc huller which decorticated and discharged the cut seed direct to the shakers of the separator. In the huller the position of the discs may be varied with a tempering screw in order to control the amount of pellicle to be left on the seed. The separator does its work through both mechanical and pneumatic action. The decorticated seeds from the huller are sifted on to shaking trys, the loose kernels falling immediately to the lower tray. The coarse bulk, consisting of outer hulls, then passes over the upper tray until the mass comes within range of the aspiration chamber where it is lifted by suction, passed through the fan, and delivered to the cyclone collector which may be placed in any convenient location. The cyclone collector is part of the apparatus. Before being discharged from the end of the lower tray, all of the separated seed is purified by air suction which removes small particles of hull, etc., which may have passed through the perforations of the upper tray.

The rate of working was an intake of approximately 3,000 lbs. of fruit per hour. The return was 36 per cent. of shelled seed ready for oil crushing purposes, substantially free from the hard pellicle or skin (which contains no oil); only a sufficient

quantity of skin being allowed to go through with the seed to give a satisfactory " bond " for proper expelling results. The seed must have been extremely clean and dry to have analysed 44 per cent. oil.

These experiments indicate that the total cost of seed preparation, including running expenses, interest, depreciation, repairs, etc., will be less than 2 dollars per ton of fruit which is said to compare favourably with the expense of preparing other types of seed.

The decorticated seed was part solvent extracted and part pressed in a French Cage Press hydraulic installation and in an Anderson expeller.

The solvent extraction process test was not entirely sucessful owing to the difficulty of cleaning up the plant before the test was carried out. The result was that practically nothing was obtained free from cocao butter for which purpose the plant was generally used. It also appeared that the recovered oil was likely to change over to the solid form through contact with the solvent.

The principal object of the hydraulic pressing tests was to determine the effect of temperature and pressure on the quality and yield of the oil. A Diamond attrition mill was found to produce a satisfactory meal, which was tempered for from 60 to 80 minutes at final temperatures ranging from 140° to 192° F. Having regard to the very large size of the plant and the limited amount of material available it is not surprising that the conclusion was reached that the data obtained as to the most satisfactory method of operating cage press type of plant on tung nuts was inconclusive. The oils obtained were inclined to be cloudy, with an acid value greater than unity and the oil content of the press cake was high compared with the press cake from the Anderson expeller. The Anderson expeller oil was clear with an acid value of 0·2.

The Anderson expeller equipment used for the tests was the standard type consuming 15 h.p. costing in all about 5,000 dollars. The machine was expected to press from 500 to 800 lbs.

of seed per hour, but has since yielded approximately 50 gallons of oil per hour, with an overall estimated expense for crushing of 8 dollars per ton of fruit.

The following figures were obtained in this work :—

Percentage of oil based on ground seed	43·7%
Percentage of oil based on oil-cake and foots ...	46.6%
Average amount of oil left in cake	5·3%
Average moisture in cake	5·2%
Protein in cake	37·8%
Oil in nuts before pressing	48·8%
Moisture in nuts before pressing	6.4%

To summarise

1,000 lbs. fruit yielded.

640 lbs. husk, etc. + 360 lbs. clean meats which in turn yielded.

460 lbs. outer husk.	165 lbs.	158 lbs.	16 lbs.	21 lbs.
180 lbs. inner shell.	cake.	filtered oil.	cleaning.	loss.

It is evident that the press cake could be produced with an oil content not exceeding 5 per cent. and special attention has been directed in America to its value as a fertiliser on account of its nitrogen, phosphoric acid and potash contents. It is now being used as fertiliser on the plantations.

Typical analyses of cake produced in the above pressing experiments are :—

—	I.	II.	III Guano value $46 per ton.
Moisture	5·4	6·7	8·6—12·8
N. equiv. to NH.	6·4	4·2	5·6— 6·7
Phosphoric acid, ...	1·73	2·70	3·5—10·9
equiv. to bone phosphate	3·78	5·90	7·6—23·8
Potash	1·28	1·20	1·2— 1·7

The potash and phosphoric acid contents of tung oil-cake as reported above have been substantially confirmed on Chinese fruit examined in England.

The early experiments on a laboratory scale made in 1924 did not yield such well-cleaned meats with the result that the cake

yield was from 66 to 74 per cent. on the weight of the nuts. Likewise the result of the analysis of this cake was poor, the ammonia content ranging from 3·9-4·2 per cent., the bone phosphate equivalent from 1·7 to 2·6 per cent. and the potash from 0·9-1·1 per cent.

It is generally considered in America that the fertiliser value of the cake will offset the cost of crushing.

No steps have yet been reported as to investigating the value of the cake as a feeding stuff, probably because animals do not eat the fruit when lying on the ground.

The outer husks removed from the seed are practically useless even as fertiliser containing only about 9.6 per cent. of available ammonia, but their return to the soil would add appreciably to the humus content, and this would be an important matter on sandy soil.

Yields.—Chinese trees yield from 1 to 5 bushels of fruit per season according to age.

The kernels form approximately half the weight of the fruit and contain 58·3 per cent. of oil by analysis.[34] The usual yield in practice is 40 per cent.

It has already been shown that American experiments identified 48·8 per cent. oil in the nuts of which 43·7 per cent. was pressed out, and that 6 lbs. of fruit will yield 1 lb. of oil.

Some young trees begin to fruit in the third year, but they may be expected to fruit on a commercial basis by the fifth year; a tree will be yielding its maximum crop in the ninth or tenth year, and may be expected to have a useful life of about thirty years. Information as to the yields of fruit actually obtained is scanty as yet, but the following is an example of the kind of information which is available :—In 1926 a grove of 109 trees in South Alabama (presumably three-year old trees) yielded 5,500

lbs. of fruit, equivalent to approximately 8½ lbs. of oil per tree. There is apparently much variation in the yields of fruit obtained from individul trees of similar age and maturity, two and three times the above amounts having frequently been noted; many trees have yielded so well as to suggest that a substantial proportion of the American plantation trees will have a mature crop considerably above the average yield obtained in China. As yet figures of yields are not adequate to make reliable estimates, but the following table is regarded in America as a reasonable prospect.[35]

Age.	Fruit in bushels per tree.	Trees per acre.	Weight of nuts per tree.	Weight of oil in lbs. per tree.	Value per acre at 15 cents. for 1 lb. of oil.
4	0·5	116	8·5	2·9	56 dollars.
5	1·0	116	16·5	5·6	100 ,,
6	2·2	116	36·0	12·0	210 ,,
7	3 0	116	52·0	17·6	310 ,,
8	3·7	58	60·0	20·5	175 ,,
9	3·8	58	63·5	21·6	185 ,,
10	4·1	58	67·0	22·8	195 ,,
after 10	4·3	58	70·0	24·0	200 ,,

According to Gardner the comparative yields of oil of various crops, including tung oil, are as follows :—

	Max. yield per acre.
Cotton seed oil	150 lbs. weight.
Ground nut oil	300 ,,
Linseed oil	255 ,,
Tung oil	400 ,,
	to 1,800 in the ninth year.[36]

Plantation Costs.—No information is available giving an actual or estimated balance sheet of the American Tung Oil Corporation.

The following estimated cost[37] was prepared by Mr. Gardner in January, 1924, to cover the first three years' activities.

The total cost of the plantations is estimated at 154 dollars per acre on the 1,000 acre basis for the whole three years.

TUNG OIL.

Cost per Acre, First Years, 1,000 Acre Basis.

Fist Year.

		Dollars.
Land per acre		20.00
Clearing, ploughing and harrowing sixty stumps, average per acre, at 15 cents.	9.00	
Tractor, ploughing twice, at 3.00 dollars	6.00	
Piling and burning rubbish	2.25	
Draining, ditching, etc.	10.00	
Harrowing, 3 times, at 1.50 dollars	4.50	
Invisible cost	3.25	
Less	35.00	
Estimated salvage, wood and log sales	5.00	
		30.00
	Dollars.	
Seventy-three trees per acre		
Cost of tree up to planting .20	14.60	
Planting and watering .10	7.30	
		21.90
Fertiliser, well balanced, strong in nitrates cost 40.00 dollars per ton.		
First year applied twice, 2 lbs. each application per tree, 4 x 73—292 lbs. at 2 cents.	5.84	
Labour applying fertiliser—One dollar per acre per application	2.00	
One extra hoeing	1.00	
		8.84
Harrowing three times at 1.50 dollars		4.50
Fencing (48-inch hog proof wire)—Cost of fencing 640 acres, 1 mile square : 32 rolls of 660 feet at 18.00 dollars	576.00	
Posts, 2,112 at 10 cents.	211.20	
Labour, per panel, at 5 cents.	105.60	
Staples, 300 at 8 cents.	24.00	
Cost per 640 acres	916.80	
Cost per acre		1.43
		86.67

Second Year.

Fertiliser well balanced; Increase 50 per cent. over first year; two applications	8.76	
Labour, 1.00 dollar per application, 2 applications	2.00	
Harrowing twice at 1.50 dollars	3.00	
Seed; beggar weed, peas or beans	3.50	
One extra hoeing	1.00	
		18.26

Third Year.

About the same as second year	18.26
	123.19
For overhead and contingencies 25 per cent.	30.79
	153.98

The Corporation started in 1924 with 270 acres, but they had planted up some 1,400 acres by 1926, and raised nearly half a million seedlings, at which time the paid-up capital of the Corporation was 87,600 dollars. It would, therefore, seem as if the original estimates were not very far wrong. Up to the fifth financial year there would be no income worth speaking of, but Mr. Gardner estimates four year old trees to yield 50 dollars per acre, five year old trees 100 dollars, rising gradually to 200 dollars at ten years of age.

It is generally accepted that collection and crushing costs are offset by the value of the cake as fertiliser, although the capital for the crushing plant would have to be provided. It would be also safe to assume a standing charge of 20 dollars per acre for upkeep.

This would leave a balance of 30 dollars per acre of bearing trees in the fifth financial year. This would be sufficient to carry the outgoing expenses on an estate on which only 40 per cent. of the trees were bearing, which might well be the case.

Thereafter, all being well, the cash balance would quickly increase as more trees came into bearing, and there is room to heavily discount the estimated values as given by Mr. Gardner and still repay all the capital advanced within ten years from the start.

Quite recently much more information[38] has come to hand as to cost of plantations. Experience shows that 200 dollars per acre is a safe figure to cover the cost of planting and carrying them through with the necessary cultivation and fertilisation for a period of five years. Of this sum 50 dollars is allowed for cost of land and clearing. Large tracts of cut-over land are said to be available in Florida at from 5 to 20 dollars per acre.

Specifications for Raw Tung Oil Summarised

	American[39]		British[40]		Australian[41]	
	Max.	Min.	Max.	Min.	Max.	Min.
Spec. Grav. at 15·5°C. ...	0·943	0·939	0·943	0·939	0·943	0·939
Acid No. (alcohol/benzol) ...	7·0	...	5 0	...	8·0	...
Saponification No. ...	195·0	190·0	195·0	189·0	195·0	189·0
Unsaponifiable matter % ...	0·76	...	0·75	...	0·75	...
Refractive index at 25°C.	1·50	1·515	1·522	1·518	1·520	1·515
Heat test in minutes (A.S.T.M. or as defined ...	12 0	...	12·0	...	12·0	...
Iodine No. (Wijs) ...	...	163	167	155	...	163
Insol. Bromides ...			none		none	

Statistical Appendix concerning Tung Oil

[42]Import into Great Britain from China :—

1921	3,372 tons.		1925	3,057 tons.	
1922	1,384 ,,		1926	2,515 ,,	
1923	3,586 ,,		1927	2,833 ,,	
1924	2,836 ,,				

[43]Export from China to Great Britain :—

1923	2,900 short tons.		1926	2,900 short tons.	
1924	3,180 ,,		1927	2,660 ,,	
1925	2,300 ,,				

Total Exports of Tung Oil from China :—

Year.	Tons.	Values in dollars per picul (133 lbs.)	Year.	Tons.	Values in dollars per picul (133 lbs.)
1912	34,690	5·33	1920	32,184	15·5—18·5
1913	37,600		1921		
1914	26,150		1922		
1915	18,470		1923	49,520	17·3
1916	35,670		1924	53,100	23·0
1917	23,900		1925	53,000	
1918	29,600		1926	44,540	
1919	36,520		1927	53,650	

Exports of Tung Oil from China to other countries :—

	Tons.								Value.
	1918	1920	1922	1923	1924	1925	1926	1927	1927
Hong Kong	.....	.....	2,700	6,400	4,400	1,728	1,186	7,957	£266,797
Great Britain	1,765	1,679	1,039	2,900	3,180	2,300	2,900	2,660	145,170
Denmark	.....	.....	...	130	298	153	144	202	11,072
Germany	.....	.....	2,260	3,660	4,720	3,770	4,738	3,238	176,855
Holland	.....	.....	.....	300	475	620	927	3,429	186,884
France	.....	.....	.....	370	975	845	1,193	815	44,470
Belgium	.....	.....	.....	45	157	160	198	205	11,138
Japan	.....	.....	.....	24	736	356	457	391	20,769
Singapore	.....	.....	...	6	26	55	53	47	2,292
Italy	.....	.....	.....	116	365	264	225	327	18,067
Canada	.....	.....	33	86	510	620	.....	.....	.....
U. S. A.	14,311	22,616	36,747	35,300	37,200	42,000	37,055	40,023	1,895,830
Australia	.....	.....	.....	55	72	172	88	3	146
TOTAL ..... (approx.)	29,100	32,200	—	49,500	53,100	53,000	44,540	53,650	£2,795,997

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(Compiled by Miss S. M. Snelus, F.I.C.).

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General view of a tea garden in the Dooars.

TEA IN NORTH-EAST INDIA, III.

By

P. H. Carpenter, F.I.C., F.C.S.,

Chief Scientific Officer, Indian Tea Association.

(Continued from Vol. XXIII, Pt. 3.)

Tea soils of North-East India.

Most of the tea soils of North-East India are what is classed by geologists as new alluvium. As the Assam Valley was formed with the upheaval of the Himalayas to the north and the raising of the Barail range to the south, between what is now Assam and Burma, the Brahmaputra and its tributaries laid down soils which have from time to time been washed away or covered with newer deposits.

Near the Himalayas, in the Dooars and at the foothills along the north bank of the Brahmaputra, tea is often put out on the gentle slopes rising to the hills. These slopes, formed from the detritus washed down from the mountains, form banks of well drained loams of a bright red colour and referred to as Red Bank. In the Dooars and the Terai are also new alluvial soils washed from the areas in the immediate vicinity. The soils laid down by the Brahmaputra are generally high in insoluble silicious matter, but the alluvial soils of the Dooars contain less quartz and more minerals decomposed by acid.

In the Surma Valley the soils vary according as they are taken on *teelas,* flats or *bheels*. The *teelas* are hillocks of red sandstone, closely related to the sandstones of the Naga Hills in the Brahmaputra Valley. The valleys or flats between these hillocks may be sands or clays according to the slope of the land, for these areas are generally formed by washings from the *teelas* or by deposits laid down by rivers which have backed up during flood periods of the river Surma. The *bheels* are peaty bogs usually surrounded by *teelas*.

General view of a tea garden in the Dooars.

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The general slope of the Brahmaputra Valley is greater than 6 inches per mile with the result that most of the silt is carried away by the river and only the coarser particles deposited. In cases where loams occur, as on the Doom Dooma bank, the soil has been deposited by smaller rivers which may have had their slope changed from time to time with the successive rises and falls of the valley.

The gradient of the valley is shown by the following heights of towns, given in feet above sea level.

Sadiya	... 440 ft.	Tezpur	... 256 ft.
Dibrugarh	... 340 ft.	Gauhati	... 163 ft.
Sibsagar	... 319 ft.	Goalpara	... 150 ft.

The distance from Sadiya to Goalpara is about 400 miles.

The south bank of the Brahmaputra, backed as it is by the sandstones of the Naga Hills, yields soils devoid of stones except near the Mikir Hills and Shillong plateau. Stones are abundant in the Dooars and on the north bank as far as Brahmakund, above Sadiya, where the Himalayas end, and the crystalline rock gives place to sandstone.

The first table shows typical soils from the Brahmaputra Valley.

BRAHMAPUTRA VALLEY.

Typical soils.

	Dibrugarh	Jorhat	Bishnath
Mechnical analysis.	Per cent.	Per cent.	Per cent.
Coarse sand	16	5	56
Fine sand	34	55	24
Silt	12	18	11
Fine silt	15	11	2
Clay	17	6	3
Loss on ignition	5·9	2·9	3·2

	Dibrugarh	Jorhat	Bishnath
Chemical analysis.	Per cent.	Per cent.	Per cent.
Organic matter (Grandeau)	1·8	1·4	1·3
Nitrogen	0·10	0·08	0·08
Total Phosphoric acid	0·087	0·04	0·057
Available phosphoric acid	0·015	0·008	0·011
„ potash	0·015	0·008	0 005
„ lime	0·16	0·016	0·038
Acidity (Hopkins)	650	500	300
Insoluble silicious matter	79	93	90

The Dibrugarh soil is typical of the Lakhimpur District which comprises about 100,000 acres of tea and the finest area in North-East India. The soils here have been laid down by the Dehing and Noa Dehing river systems and thus came from the Naga Hills. On this account they show a lower percentage of insoluble silicious matter than do the soils laid down by the Brahmaputra. Besides being well supplied in plant food they are deep soils.

The Jorhat soil is taken from near Tocklai and represents the average soil of the district. The insoluble silicious matter is high and the soil generally poor. The crop in such areas is naturally far below that of Dibrugarh.

The Bishnath district is on the north bank where the soil is often light and poor. This district suffers from drought on account of the lightness of the soils, although once the tea is established it does well.

The second table contains an example of a Darjeeling soil formed *in situ,* a Red Bank soil, a Mal sand and a grey sandy loam, all from the Dooars. These last three types also occur on the Terai.

Darjeeling and Dooars.

Typical soils.

	Darjeeling	Mal sand	Red Bank	Grey sandy loam.
Mechanical analysis.	Per cent.	Per cent.	Per cent.	Per cent.
Coarse sand	23	64	19	5
Fine sand	10	16	10	31
Silt	13	4	12	29
Fine silt	27	7	18	25
Clay	20	4	33	6
Loss on ignition	6·80	4·8	7·8	3·5
Chemical analysis.				
Organic matter (Grandeau) ...	5·22	2·4	2·8	1·4
Nitrogen	0·18	0·12	0·12	0·09
Total phosphoric acid	0·09	0·081	0·15	0·16
Available phosphoric acid ...	0·019	0·019	0·014	0·06
„ potash	0·04	0·009	0·018	0·017
„ lime	0·05	0·02	0·028	0·145
Acidity (Hopkins)	840	150	800	120
Insoluble silicious matter ...	71	85	68	82

The Darjeeling soil is typical of many formed *in situ* in this district, although some resemble the Red Bank soil shown in another column. The accumulation of fine silt appears to indicate a distinction for this class of soil. In the valleys of Darjeeling, many of the soils are alluvial resembling the Mal sand and grey sandy loam of the Dooars.

The Mal sands occur in the Terai and the western Dooars and are probably old alluvial deposits which have remained water-logged and thus collected plant food, in which they are now remarkably rich. The insoluble silicious matter is lower than might be expected, suggesting that much of the sand of these soils is soluble in acid and is not quartz as is the case generally in Assam. The Mal sands are black, but in the south Terai are examples of these soils raised on banks and well aerated. The result is a red Mal sand much poorer than the average black type.

The Red Bank soil may be taken as typical of most of these soils formed by weathering. The characteristic is coarse and fine particles as major fractions, a state of affairs not possible with water borne soils. The Red Bank soils are among the richest tea soils of North-East India. The Red Bank generally abuts the Hills, although in one or two cases isolated outcrops occur.

The grey sandy loams are the newest soils in the Docars and as such are rich in lime and phosphoric acid. In some cases patches of alkaline soils occur, and here the tea is poor or fails to grow at all. It is usually found that, within limits, the best tea soils are the most acid ones.

The third table shows soils from the Surma Valley.

Typical Surma Valley soils.

	Teela	Flat	*Bheel*
Mechanical analysis.	Per cent.	Per cent.	Per cent.
Coarse sand	32	*nil*	*nil*
Fine sand	36	17	7
Silt	6	16	7
Fine silt	9	27	26
Clay	11	28	11
Loss on ignition	5·6	8·4	33·0
Chemical analysis.			
Organic matter (Grandeau)	2·4	3·7	20·4
Nitrogen	0·15	0·20	0·57
Total phosphoric acid	0·34	0·068	0·194
Available phosphoric acid	0·16	·005	0·053
„ potash	0·13	0·014	0·036
„ lime	0·06	0·083	0·024
Acidity (Hopkins)	500	1200	2500
Insoluble silicious matter	92	75	55

The *teela* soil is typical of the red hillocks which are a distinctive feature of Cachar and Sylhet. These *teelas* carry good tea, although some of the southern slopes suffer badly from drought and too much sun.

The flat is a common type of heavy clay, difficult to handle unless generously green-cropped. The *bheel* is also typical.

These peat soils produce enormous crops, up to 2,000 lb. of tea per acre. After twenty years or so they deteriorate, often owing to over drainage, as a result of which they lose their colloidal properties through repeated drying, and become "fluffy."

Practically all the tea soils of North-East India are acid. In a few cases in the Daina-Toorsa district of the Dooars small patches of recently deposited soil are neutral or just alkaline, and either fail to grow tea, or do so indifferently. The higher limit of soil acidity tolerated by tea has not yet been fixed, but soils with an acidity as high as 3,000 parts lime per million (Hopkins), and a p^H value as low as 3.8, grow good tea. Soils showing practically no acidity by the Hopkins method but a p^H value of about 6.5 may be successful as tea soils, but a neutral soil with $p^H = 7$ is not good for tea.

Planting.

The most sought after land for tea planting is well drained jungle land, although great areas of grass land are also growing fine tea. Low-lying land, usually referred to as rice land, does not do well unless it is sufficiently high lying to be drained. Many of the best areas in Assam were formerly occupied by bamboo forest and the *teelas* of the Surma Valley carry bamboo.

Tea seed is grown in seed gardens which are usually attached to tea gardens. North-East India, with its dry, cold weather, is particularly suited to the formation and ripening of tea seed, and in most districts are good seed gardens from which are annually despatched many maunds of seed to the tea growing districts of the world.

Some of the best known seed gardens are planted out as follows. The bushes are planted 10 × 10 feet square and centre pruned when about 4 years old. After about 10 years, alternate diagonal rows of bushes are cut out leaving the planting 14 × 14 feet triangular. The stems of the bushes are kept clean and sprayed with lime-sulphur solution to a height of about 5 feet.

The method of collecting and sorting tea seed is as follows. The seed pods and seeds are collected after they have fallen and placed in damp, shallow sand pits, covered with dried grass, for a few days, after which time the pods are easily removed. After shelling, the seed is placed in a water-tank and, of the sinkers, a certain number are split and examined. If these are 90 per cent. or more good (*i.e.*, not more than 10 per cent. "starred") they are dried and sold. If they show less than 90 per cent. sound they are put back in the pits for four or five days and then refloated and a fresh test made of the sinkers. A "starred" seed is one which has been attacked by the tea seed bug (*Poecilocoris latus*) and shows a white patch when it is cracked and opened.

The light seeds or floaters are also tested and if they contain less than 50 per cent. good seed, they are burnt. If there are 50-60 per cent. good, they are put back in the pits for four or five days and then again put in the water-tank. The sinkers are tested as before.

The sinkers which have passed the test are dried weekly in the sun and the split seed removed. Split seed, however, is capable of growing good plants.

It will be understood that on putting out a seed garden it is necessary to pick the seed bushes with care. Broadly speaking, there are four varieties of tea bush seen in tea gardens in North-East India, the China, the Assam or light-leaved indigenous, the Burma or dark-leaved and the Manipuri bush. In the plains districts of North-East India the large-leaved varieties are preferred. The dark-leaved bush is hardier than the light-leaved Assam bush, and although both yield about the same, the Assam bush is thought to give the better tea. In Darjeeling, where the climate is severe, the China type of bush is preferred. In the Dooars and the Surma Valley, where climatic conditions are often difficult, the dark-leaved variety is favoured, but in the Brahmaputra Valley the light-leaved bush of the Assam, Burma or Manipuri varieties is preferred generally.

Light-leaved seed bushes yield about 5 maunds of seed per acre, and dark-leaved about double that quantity.

Tea is planted out from seed which it is preferable to germinate before planting in the nursery. This does not ensure better plants but a more even nursery. The seed is generally available in November or December and the nurseries are put out as early as possible.

The nursery bed is usually made in the jungle, conveniently near the area to be planted. The soil is thoroughly cleaned but not hoed too deeply, otherwise the lifting of clods when the seedling is transplanted is a difficulty. The seeds are planted at distances varying from 4 inches to 8 inches square according to the age at which the plants will be lifted. Experiment has shown that the following distances are advisable :—

For 6 months plants, plant 5 in. apart.
,, 12 ,, ,, ,, 8 ,, ,,
,, 24 ,, ,, ,, 10 ,, ,,

The seed-bed, which is usually about 5 feet wide, is well drained and shaded, either by grass laid on as a mulch or by overhead grass shading, supported by a bamboo framework. Experiments have shown that shade about 5 feet high yields the best results. In a season which starts with a bad drought a nursery may be a total failure unless it is shaded, and even in good years, shading increases the number of successful seedlings by as much as 50 per cent. Shade is sometimes provided by sowing dhaincha (*Sesbania aculeata*) near the beds during the first spring.

The seeds are planted about half an inch deep with the eye downwards. This latter is an important point, because a straight good tap root, without any twist, is necessary to a good tea plant. It the tap root is not sound or if it is damaged or cut in transplanting, it is likely that the bush when it matures will be a poor leaf yielder.

Tea seedlings are generally replanted at about 8 to 14 months, and only selected plants are removed from the nursery. The plant is lifted intact in a clod of earth. If the clod is broken during lifting or in transit, the plant is discarded, otherwise it is carefully carried to the clearance where a hole has been dug for its reception.

Sometimes seed is planted at stake in a clearance. It is usual in such cases to plant three or four seeds at each stake and to uproot all but the best when the seedlings have grown big enough for selection. In the case of a bad drought, seed at stake suffers badly since it is usually impracticable to water a large area.

In many cases " carrot " planting, by which method the plant is lifted without the clod, has been tried, but this method does not yield such good plants as does the clod method. In Ceylon and South India " stump " planting is a general method. With stump planting the seedling is cut a few inches above the ground and then uprooted and replanted. Most planting in North-East India is done in the dry season and on this account the clod method gives much better results.

When planting out new areas, 8-12 months old plants are best, but for infilling vacancies in planted tea or for re-planting old tea lands, older plants are often used.

The usual distance apart for planting tea bushes is 4 ft. 6 inches triangular which gives 2,483 bushes per acre. There are on an average about 16,000 tea seeds in a maund (80 lb.) and about 3 or 4 acres of tea planted out from this number of seeds. The loss is accounted for by bad seed and weakly seedlings.

Pruning.

Growing wild the tea plant is a tall shrub and it is converted into a bush of convenient pluckable height by pruning.

The young tea plant is made into a bush by one of two methods. The first is to let it grow for 2 or 3 years and then

to cut it between one and four inches above the ground. By this method a secondary or coppice growth is induced and the bush takes on a spread. This method was once popular in Assam but has lately been to some extent changed. Another method is to cut the young plant straight across at about 18 inches and to remove one or more of the central branches. By this means the bush is made to spread without cutting a thick piece of wood.

At the Experimental Station at Tocklai many methods of forming a young tea bush have been tried, and the conclusion arrived at, is that centring is preferable to collar pruning, as low cutting is termed, for giving a big crop during the early years. After collar pruning the next cut is sometimes made as high as about eighteen inches or just below one foot. The lower cut gives a wider bush than the higher one.

Most of the tea—at least 90 per cent. on established gardens —consists of formed bushes which are top pruned each year or every other year. The object of top pruning is to cut the bush back leaving about one inch of last year's wood and at the same time removing weakly twigs. Thus each year the woody portion of the bush gets higher, until finally it is too high to pluck. When this is the case the bush is heavy pruned.

Heavy pruning is undoubtedly the most difficult problem in pruning. In Upper Assam it is common to cut the bush right down to the ground at intervals of 20 years or less, and to build up a new frame again. In other districts it is the custom to cut the bush through where the spread is fairly broad, back to thick wood. In this case the bush sends out new shoots from an inch or often much more below the cut and a dead piece of wood remains. These dead snags form entry places for fungus diseases which may kill the entire branch and eventually the bush. The more healthy the bush the less are snags liable to form, and on this account it is advisable to manure tea well and to pluck it lightly the season before it is cut back.

In Ceylon, South India and Java, where the bush flushes all the year round, it is usual to prune every other year or at

some of the higher elevations every three, four or even five years. Such a custom also holds in Darjeeling, not because the bushees flush continuously but because the growth is slow.

In many districts in North-East India it is customary to leave a large percentage of the tea unpruned each year. Thus when the bush stops flushing in November or December it is left till the next March or April, when the spring flush appears, and is then again plucked. The advantage from this system is that the crop is gathered early when labour is available. A grave drawback to unpruned tea is the risk of severe early drought, in which case the bush carrying full foliage suffers badly. Another disadvantage is that unpruned tea invariably suffers from fungus attack and from red spider much more than does pruned tea.

At the end of the plucking season it often happens that the top of the bush is irregular because it has not been possible to pluck the leaf as fast as it grows. In this case " skiffing " or " switching " is sometimes practised. This consists in cutting the bush across level, just below the last season's plucking marks. By this means the foliage is reduced and a flat plucking surface is formed, ready for the coming season.

Tea cannot be left unpruned indefinitely for with each season the leaf becomes smaller and more difficult to gather and eventually too much flower is produced at the expense of leaf. In addition, leaving bushes unpruned is a strain on the plant and one year of such treatment is generally considered enough. Apart from the problem of labour for plucking and pruning, the gain from biennially pruned tea over annually pruned tea is small over a period of years, even in the absence of severe droughts.

The best time for collar pruning tea in North-East India is September, when the food stores of the plant are at a maximum. This is seldom carried out in practice, however, because it entails the loss of half the season's crop on the collar pruned area. In pruning, the effect of the drought must always be kept in mind,

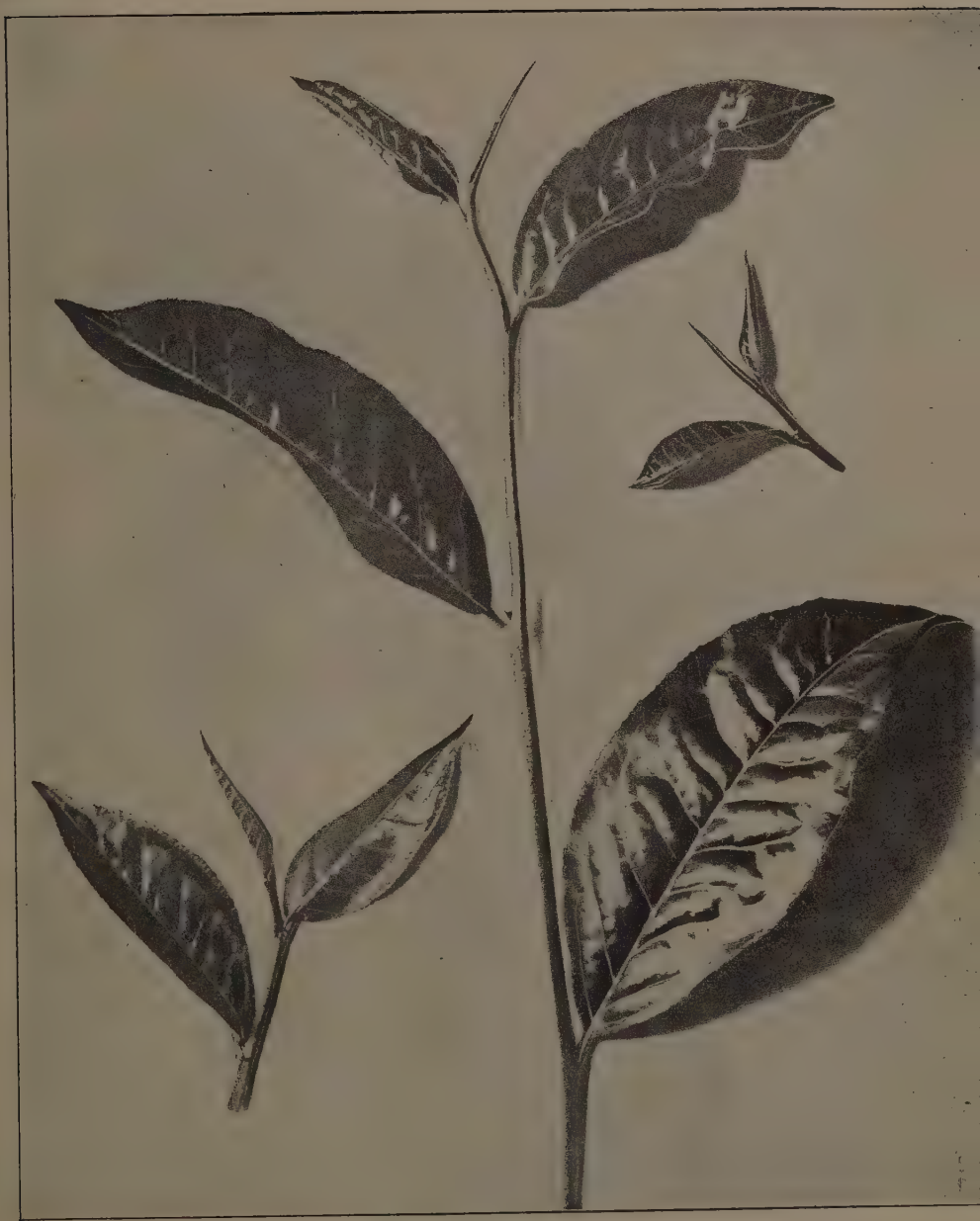
for the conservation of soil moisture is a problem of prime importance. A bush in full foliage takes much moisture from the soil and it sometimes happens that if the pruning is done at the end of February or in March, the soil has become so dry that when the spring flush appears, as it does whether the rains have started or not, there is insufficient soil moisture for it to carry on. The result is a bad start to the season. Top pruning is done in December and January, followed by deep cultivation with which the prunings are buried.

Plucking.

After a bush is pruned, buds burst from the wood and a new shoot begins to grow. The first leaf that unfolds is not a normal, serrated leaf, such as usually grows on the bush, but a small, smooth edged leaf known as the *janum* (Hind.—birth). The next leaf may also be misformed, but usually is of normal growth and size.

If the shoot is left to grow and the bush is vigorous, it elongates throughout the season, growing fastest in the spring and autumn. If the bush is a weakly one or if the branch is weak, as many side branches are, after the growth of four or five leaves comes a resting period, during which the bud ceases to grow or becomes *banjhi* (Hind.—sterile), but the leaf beneath it develops normally. After a variable period, perhaps as long as twelve weeks, the *banjhi* shoot again begins to grow with the formation first of a *janum* leaf, and then of a series of normal leaves.

It is common to pluck two leaves and a bud for tea making, although often three or four leaves are taken if the object is to make a large crop rather than a fine tea. In North-East India it is usual to fix on a plucking height and to take all shoots of two leaves and a bud which appear above this height. This height, measured from the ground, is seldom below 27 inches and is often much higher. On tea which has been medium pruned at



TEA SHOOTS, NATURAL SIZE.

It is usual to pluck two and sometimes three leaves and a bud.

least 9 inches of new growth is allowed before plucking. On a top pruned bush 6 inches is left. Six inches equals about three leaves growth in the centre of a vigorous bush.

The correct plucking of a bush is the most important operation on a garden, since too severe plucking may ruin the health of the bush and too light plucking may result in a serious loss of crop. When the height of the tipping, as the first plucking is called, is fixed, there are still several ways of plucking subsequently. The most severe method is to continue to pluck all shoots of two leaves and a bud which appear above the plucking table. A more lenient method is to let the new shoots grow to three leaves and a bud and then to pluck two and a bud, leaving one fully developed leaf. In some areas, notably the Dooars and Surma Valley, it is common to let the shoot grow to four leaves and a bud and to pluck above two big leaves after the first tipping. When the shoots have reached the second level, the next shoots are either plucked as soon as they develop to two leaves and a bud above that level, or three leaves and a bud are allowed to develop and two and a bud are plucked. The bush thus gets higher as the season advances.

As already stated, in some gardens where the tea is vigorous, the bush is plucked down at the original plucking level, but generally some growth is given on the second flush and after that a level plucking surface is aimed at. Often, owing to labour shortage, the shoots grow long before they can be plucked and then only the top of the shoot can be taken. At the end of the season the tops of the bushes on many gardens thus present an irregular appearance.

Nowadays the advantage of not plucking the sides of the bushes till they grow level with the plucking table is realized. By this treatment a greater plucking surface is obtained, for the sides eventually strengthen up till they are almost as strong as the centre. A still greater advantage accruing from this treat-

ment is that the soil is covered with foliage and weed growth retarded.

In North-East India the bushes begin to flush with the spring impulse in April or May, and the first tipping is made at a definite height. The second flush comes in about June, and the teas then made are well supplied with " tip " and bring high prices. The gardens of Upper Assam produce much " tip " because the pruning in this area is severe and the early shoots produce fat buds which, on rolling, display the ultimate bud leaves. These small leaves remain a golden colour after manufacture and constitute the " tip." Unpruned tea or tea which has not been cleaned out in the pruning gives little "tip."

There are, broadly speaking, six flushes in the season although the bushes are plucked every week if labour is available. After the second flush, which is a very definite one, the others are not well marked because shoots growing from axils below the plucking table in time reach the plucking level and give a continuous supply of leaf.

The autumn teas usually possess flavour which brings big prices. The flavour is believed to be due to the slower rate of growth at this period. During the hot rainy season, a shoot takes about three weeks to develop from an axil after the shoot above has been plucked. In the autumn, the growth may take as much as six weeks according to climatic conditions.

Plucking may be coarse or fine, close or long. Fine plucking consists in two leaves and a bud and coarse plucking in three or four leaves. Fine plucking makes for quality. The composition of a shoot by weight is shown below.

Bud ...	...	14 per cent.	of shoot	plucked.
First leaf	...	21 ,,	,,	,,
Second leaf	...	38 ,,	,,	,,
Stalk	...	27 ,,	,,	,,
		100 ,,		

The tannin content of the various leaves and stalk are shown below.

	Tannin per cent.
Bud	27·9
First leaf	27·9
Second leaf	21·3
Third leaf	17·8
Fourth leaf	14·5
Upper stalk (Bud to second leaf) ...	11·7
Lower stalk (2nd to 4th leaf)	6·4

Long plucking means plucking at a distance from the old wood of a bush. Tea which has been heavy pruned must be plucked on a long growth of new wood, otherwise the bush suffers. As the bush gets older and the top wood thickens up, the plucking may be made close, to within about six inches, of this wood. Close plucking makes better tea than long plucking, and the best tea is made by plucking close and fine.

(To be continued.)

PROPOSED TOURING PROGRAMME OF THE OFFICERS

OF

THE SCIENTIFIC DEPARTMENT.

Season 1930.

Months.	P. H. Carpenter	H. R. Cooper.	C. R. Harler.	C. J. Harrison.
January ...	.....	.....	Nowgong and Kamrup.	Moran
February ...	.....	.....	.....	.....
March ...		.....	Behali and Bishnath	.....
April ...	HOME LEAVE	.....	Happy Valley	.....
May ...		Nazira	.....	.....
June ...		.....	Panitola and Dibrugarh	Doom Dooma and Mergherita
July ...		.....	.....	Chargola and Longai
August ...		Tingri	.....	.....
September ...		.....	Longla Dholai Juri	Darjeeling and Terai
October ...		Tezpur and Orang	.....	.....
Novemher ...	.....	.....	.....	.....
December ...	.....	.....	.....	.....

The other Officers of the Department will tour only as the investigations that they are carrying out necessitate. Mr. Andrews will be on home leave.

The exact dates of the above tours will be given later to the Sub-District Chairmen. Managers desiring a visit from the Scientific Officer must inform the Sub-District Chairman who will make out a tour itinerary.